

Assessment of the Risk of Escapement of Redear Sunfish from Lake Powell

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Purpose: The purpose of this document is to review the life-history and ecology of redear sunfish *Lepomis microlophus* with the goal of determining whether the species can become established within tributaries of Lake Powell.

Introduction:

Redear sunfish *Lepomis microlophus* are a centrarchid species that are popular among anglers. They are native to the Mississippi River drainage from Missouri and southern Illinois ranging south into Florida, and west into Texas (Trautman 1957). They have also been successfully introduced into many areas including Michigan (Towns 2003), Arizona (Minckley 1993), and California (Wang 1986). Similar to most sunfish species, redear sunfish form spawning colonies and males construct nests. The males guard the nests and offspring and spawning is known to occur throughout the summer months. Redear sunfish are known to specialize on feeding on mollusks (Minckley 1982) but are known to feed on other invertebrate taxa as well (Minckley 1982).

Lake Havasu, Arizona is known as a "world-class" redear sunfish fishery and produced the largest redear to ever be caught by an angler in 2014. Redear sunfish have been in the reservoir since the 1940's (Minckley 1973). Trend netting data on redear sunfish within the reservoir is not available (Karp and Thomas 2014) but angler reports indicate that the size of redear sunfish has increased since quagga mussels invaded the reservoir in 2007 (Karp and Thomas 2014). Redear sunfish have been shown to feed heavily on quagga mussels (Magoulick and Lewis 2002) and it has been suggested that redear sunfish could be an effective biocontrol agent on quagga mussels (Wong et al. 2013). Redear are not the only fish species that feeds on quagga mussels, however. Magoulick and Lewis (2002) noted that both blue catfish *Ictalurus furcatus* and freshwater drum *Aplodinotus grunniens* also feed on the mussel. Common carp *Cyprinus carpio* have also been shown to feed on quagga mussels (Marsden 1997). Culver et al. (2014) found that not all individual redear sunfish feed on quagga mussels and that bluegill *Lepomis macrochirus* feed more consistently on the mussel. Karp and Thomas (2014) found that the average reduction in quagga mussel density in enclosures containing redear sunfish ranged from 0-25.3% with a less than 1% reduction in 6 of 13 enclosures. In Lake Havasu, a minority of redear sunfish consume quagga mussels, but those that do consume mussels tend to consume them in large numbers (C. Karp, Bureau of Reclamation, personal communication). French and Morgan (1995) found that redear sunfish prefer to feed on rams-horn snails *Helisoma anceps* over zebra mussels *Dreissena polymorpha*.

Quagga mussels have recently become established in Lake Powell and the Utah Division of Wildlife Resources is considering the stocking of redear sunfish into the reservoir with the hope that redear will become established to help control quagga mussel numbers and to create another popular sportfishery within Lake Powell. The tributaries to Lake Powell, however, provide important habitat for many imperiled, native fishes. There are concerns that if redear sunfish are stocked into Lake Powell that they may emigrate from the reservoir into these tributaries where they could possibly predate on or compete with these native fishes. The purpose of this review is to summarize what is known about

redeer sunfish with the goal of determining whether tributaries to Lake Powell provide the physical conditions required to support redear sunfish.

Analysis:

The most comprehensive source for information on the life-history and ecology of the redear sunfish is Twomey et al. (1984). In their paper, Twomey et al. (1984) reviewed the literature on the redear sunfish and developed a model determining whether riverine habitats are suitable for the species. The model presented by Twomey et al. (1984) contains four components and ten variables and is outlined in Table 1. Each variable is scored between 0.0 and 1.0 and Twomey et al. (1984) provides guidelines on the scoring of each variable. The lowest overall score determines the suitability of a habitat to redear sunfish with 0.0 representing un-suitable habitats, 0.0-0.1 representing "poor habitats", 0.2-0.4 representing "fair habitats", 0.5-0.7 representing "good habitats" and >0.8 representing "excellent habitats".

Table 1: Overview of the four components and ten variables in the Twomey et al. (1984) model describing the suitability of habitats to redear sunfish.

Component	Variable
Food	Percent Vegetated Area in Pool Habitats
Cover	Percent Habitat > 2 m in Depth
Water Quality	Minimum Dissolved Oxygen
	Maximum Salinity
	Maximum Turbidity
	Maximum Summer Water Temperature
	pH
Reproduction	Percent Vegetated Area in Pool Habitats
	Average water velocity
	Mean Weekly Water Temperature

In this analysis, I apply the Twomey et al. (1984) model to the tributaries of Lake Powell (the Colorado, Green, and Escalante Rivers). Data for all ten variables listed in Table 1 is not available but the Twomey et al. (1984) model can be applied to the tributaries using available turbidity, temperature, water velocity, and vegetation data. I also use data from two related centrarchids, the bluegill and green sunfish *Lepomis cyanellus* to help better understand how redear sunfish would perform in tributaries to Lake Powell.

Turbidity:

The literature indicates that redear sunfish perform best when turbidity is less than 25 mg/L ; although redear sunfish have been reported to survive in ponds with turbidities as high as 174 mg/L (Childers 1967). Embryonic development appears to be impaired at turbidities > 174 mg/L (Buck 1956). The critical threshold for long-term survival and reproduction is likely between 75 and 100 mg/L (Buck 1956) and it is not likely that redear sunfish would persist long-term in waters with turbidities that exceed this critical threshold.

The tributaries to Lake Powell are known to be turbid. Data from United States Geological Survey (USGS) stream gaging stations near Lake Powell are shown in Table 2. These data indicate that average turbidities in the region exceed what redear sunfish can tolerate. There were two point samples taken in the Little Colorado River (83 and 95 mg/L; Table 2) that had turbidities within the range that redear sunfish can tolerate (< 174 mg/L; Buck 1956). The remaining samples (55 samples in total between 1950 and 1957) were well in excess of what redear sunfish can tolerate.

Table 2: Average suspended sediment concentration (in mg/L) at five sites near Lake Powell. Data are from USGS stream gages and are monthly averages across the years listed.

Site Name	Years Data Collected	Average Turbidity (mg/L)	Turbidity Range (mg/L)
Colorado River at Hite, Utah	1949-1958	2,166	533-4300
Colorado River at Lee's Ferry, Arizona	1930-1964	3,336	1,650-6,140
Paria River at Lee's Ferry, Arizona	1948-1933	13,260	1,810-55,900
San Juan River near Bluff, Utah	1941-1980	5,648	2,040-15,000
Little Colorado River at Woodruff, Arizona	1950-1957	2,481	83-10,800

The Twomey et al. (1984) model assumes that habitats with turbidities > 200 mg/L are not suitable for redear sunfish. Data from Table 2 indicates that turbidities in rivers near Lake Powell exceed this level and thus are not suitable for the species. With that said, most of the data presented in Table 2 is historical. For example, data from the Colorado River at Lee's Ferry, Arizona was collected before Glen Canyon Dam was built. The dam trapped sediment and reduced turbidities at this site and thus sediment loads at the site are now lower than what they were when the data presented in Table 2 was collected. Regardless, based on data for other environmental factors presented later in the document, it appears that the Colorado River downstream of Lake Powell is not suitable for redear sunfish. Other sites have not been altered to the same extent and turbidities at these sites are likely similar today as when the historic data was collected.

Water Temperature:

Redear sunfish reproduce at temperatures ranging between 18.3 and 32°C (Childers 1967; Clugston 1966). Swingle (1949) reports that the optimal temperature range for reproduction is 21-24°C. Temperatures of 24-27°C are optimal for growth (Emig 1966). Disease becomes a problem in redear sunfish at temperatures below 14°C and growth ceases at temperatures below 10°C.

USGS temperature data could be found from four sites in tributaries of Lake Powell (or are downstream of Lake Powell) and data from these sites is presented in Table 3. As a whole, temperatures in the region are cooler than ideal for redear sunfish. If redear sunfish were to escape into the Colorado River below Lake Powell, they would encounter water temperatures that are too cool for reproduction and growth. The cool temperatures in this stretch of the Colorado River can be attributed to the hypolimnetic release of water from the Glen Canyon Dam. Temperatures in the upstream tributaries are likely warm enough to support some reproduction and growth but are still cooler than ideal. In the Colorado River near Cisco, Utah, water temperatures are warm enough to support reproduction during three months of each year but are never warm enough to support optimal growth. Similarly, water temperatures in the Green River near Jensen are warm enough to support spawning for two months out of each year and are not warm enough to support optimal growth. The

Table 3: Average temperatures at four sites near Lake Powell. Data are from USGS stream gages and are monthly averages across the years listed.

Site Name	Years Data Collected	Average Temperature (°C)	Temperature Range (°C)
Colorado River near Cisco, Utah	2006-2015	11.9	0.3-23.7
San Juan River near Bluff, Utah	1980-2014	13.2	1.9-24.8
Green River near Jensen, Utah	1998-2015	10.5	0.8-22.1
Colorado River at Lees Ferry, Arizona	1986-2015	10.0	8.3-11.6

San Juan River near Bluff, Utah was the warmest of the sites and could support spawning for four months of each year and two months of optimal growth.

There are two temperature variables in the Twomey et al. (1984) model; maximum average summer temperature and mean weekly water temperature during the spawn. Data from the San Juan River indicates that temperatures in the river are warm enough to be suitable for redear sunfish. In contrast, the other sites provide "poor" to "fair" habitat (suitability scores of 0.0-0.2; Twomey et al. 1984).

Water Velocity:

When encountered in riverine habitats, redear sunfish prefer low gradient, low velocity stretches (Smith 1979; Shields et al. 2000). They also appear to avoid main-channel habitats and prefer side-channels (Bailey et al. 1954). Data from Illinois indicates that redear sunfish are seldom encountered in main river channels and instead prefer backwaters (M. Mounce, Illinois Department of Natural Resources, personal communication). Studies along the longitudinal profile of large rivers shows that redear sunfish only reside on low gradient, downstream portions (Brown and Ford 2002; Kiernan et al. 2012). Redear sunfish appear to be less tolerant to riverine conditions as other species and when they are found in rivers they tend to occupy pool habitats (Travnichek et al. 1995). Rypel (2011), however, found that the growth of redear in low velocity rivers was comparable to their growth in impoundments. It appears that the velocity tolerance of redear sunfish has not been tested but Schaefer et al. (1999) performed experiments on the morphologically similar bluegill and found that the maximum time that a bluegill can tolerate a sustained water velocity of 30 cm/s was 83 s.

There are several sources that provide water velocity data within tributaries to Lake Powell. Magirl et al. (2009) measured water velocity in Cataract Canyon and reported a maximum velocity of 520 cm/s with velocities in pools ranging between 150 and 200 cm/s. When looking at the Colorado River as a whole, Magirl and Andersen (2010) report that water velocities within pools range between 50 and 200 cm/s. There is limited water velocity data from the San Juan River but data from the August 2016 release from the Gold King Mine in Colorado indicated that water in the Utah portions of the San Juan flowed at an average velocity of 92 cm/s. Discharge at this time was 115% of average (USGS stream gage at Bluff, Utah), indicating that the water velocity at this time may have been slightly above average. The average velocity of lower portions of the Escalante River have been reported as 73 cm/s in riffles and 38 cm/s in pools (Stumpf and Monroe 2012). Water velocities below Glen Canyon Dam have been reported to range between 103 and 179 cm/s (Graf 1997).

Most velocity data from tributaries are based on estimates made at a single point in time and may fluctuate with season. Unfortunately, USGS stream gages generally do not report water velocities. Leopold and Maddock (1953) describe a method to estimate velocity with stream discharge data using

the formula $v = aQ^b$, where v = velocity and Q = discharge. The coefficients a and b are based on various river metrics (width, depth, etc.) but in the desert southwest, the average values for a and b are 0.32 and 0.26, respectively (Leopold and Maddock 1953). This formula allows for additional estimates of water velocity to be made and these estimates are presented in Table 4.

Twomey et al. (1984) reports that sites with velocities greater than 10 cm/s are not suitable for redear sunfish. It is apparent from the data that velocities in tributaries to Lake Powell are well in excess of what Twomey et al. (1984) reported that the species can tolerate. With that said, the velocities reported here are averages and there are microhabitats in the system that likely have slower velocities that are suitable for redear sunfish. As a whole, however, water velocities in tributaries to Lake Powell exceed what is preferred by redear.

Table 4: Estimated water velocities at five sites near Lake Powell. Data calculated based on monthly average discharges from USGS stream gaging stations. Discharge was converted to velocity using the formula provided in Leopold and Maddock (1953).

Site	Years Data Collected	Low Discharge Velocity (cm/s)	High Discharge Velocity (cm/s)	Mean Discharge Velocity (cm/s)
Colorado River at Potash, Utah	2014-2015	79	134	97
Colorado River at Hite, Utah	1947-1958	89	159	116
San Juan River near Bluff, Utah	1914-2015	60	90	75
Escalante River near Escalante, Utah	1942-2015	17	22	18
Colorado River at Lee's Ferry, Arizona	1921-2015	106	144	118

Vegetation:

Data from Illinois (M. Diana, Illinois Natural History Survey) indicates that redear sunfish are associated with vegetated habitats. In riverine systems, redear are more likely to occupy pools and backwater areas with vegetation than those without vegetation (M. Mounce, Illinois Department of Natural Resources). Vegetation is considered important nursery habitat for redear and likely provide habitat for many preferred prey species (Trautman 1957). Redear sunfish condition is best in moderately vegetated habitats (Colle and Shireman 1980). Vegetation, however, is not considered absolutely necessary for the species (Twomey et al. 1984).

Unfortunately, there is very little data on macrophytes in tributaries to Lake Powell. It has been documented that macrophytes do occur within these rivers, however (McKinney et al. 1996). This paucity of data makes it difficult to apply the Twomey et al. (1984) model. Regardless, there is enough information to assume that quantities of vegetation within the tributaries are sufficient to provide "fair" to "excellent" habitat to redear sunfish (habitat is "fair" to "excellent" anywhere where percent area containing vegetation is <80%).

Application of Twomey et al. (1984) Model:

The final habitat suitability score from the Twomey et al. (1984) model is the lowest score of the food, cover, water quality, and reproduction components (Table 1). There is not sufficient data to score all ten variables within the model (Table 1). Regardless, turbidities in the tributaries are high enough to

score the water quality component as zero and water velocities are high enough to score the reproduction component as zero. This means the overall score for the tributaries is a zero, which indicates that the tributaries do not provide suitable habitat for redear sunfish (Twomey et al. 1984).

Analysis of Bluegill and Green Sunfish Populations in Tributaries

Another method of estimating the performance of redear sunfish in tributaries to Lake Powell is to evaluate how two closely related fish, the bluegill and the green sunfish perform in these habitats. Both species are currently found in Lake Powell and have been introduced into other habitats in Utah. Rypel (2011) evaluated the riverine/lacustrine performance of fourteen sunfish species and determined that green sunfish are better adapted to riverine life than bluegill and redear sunfish are not as adapted to riverine life as green sunfish but are more similar to green sunfish than bluegill. The work by Rypel (2011), however, was performed in low gradient, warm, coastal river systems that provided nearly ideal physical conditions for all the species evaluated. Tyus and Saunders (2000) noted that pond habitats are better suited for bluegill and green sunfish than riverine habitats. Bluegill are more tolerant of turbid conditions and high water velocities than redear sunfish (Stuber et al. 1982a). Comparatively, green sunfish are more tolerant of high water velocities than bluegill (Stuber et al. 1982b). Because of this, green sunfish are 4.3 times more abundant than bluegill in the Colorado River near Grand Junction, Colorado (Whitledge et al. 2007).

Both species have been documented in tributaries to Lake Powell, albeit in low densities. Gerig and Hines (2013) sampled Utah portions of the San Juan River on eight occasions during 2012 and collected one green sunfish and no bluegill during their sampling. Sampling during 2013 documented no green sunfish and no bluegill (Hines 2014). Data from annual reports submitted to the San Juan River Recovery Implementation Program from 1998-2014 indicate that green sunfish are occasionally encountered in the river (0-5 fish collected/year) and that bluegill have not been collected within the river.

Valdez (1990) sampled the Cataract Canyon portion of the Colorado River in 1985-1988 and documented the collection of one adult bluegill in 1987. No additional bluegill were collected during the other years sampled. Numbers of green sunfish collected varied from zero in 1985 to 13 in 1986 (Valdez 1990). Some of the catch included young of year individuals. Green sunfish never constituted more than 0.10% of the total fish catch (Valdez 1990). Data from 2008-2011 shows that green sunfish and bluegill were not captured in Cataract Canyon during this time period (Badame and Lund 2010; Breidinger and Badame 2011, and Breidinger and Badame 2012). Similar samples taken in 2004 also indicated that both species were absent from Cataract Canyon (Valdez et al. 2005). Karp and Tyus (1990) sampled the Green and Yampa Rivers within Dinosaur National Monument and caught few green sunfish (<0.01% of total catch) and no bluegill. Breen et al. (2011) referred to data from samples taken from the Colorado River near Moab, Utah between 1986-2009 and noted that green sunfish were present in samples during 12 of the years of sampling and that bluegill were present during 3 years of sampling. Trammel et al. (2004) did not note the collection of bluegill in the Colorado River near Canyonlands National Park but did note that green sunfish constituted up to 0.1% of the catch. Breen et al. (2016) reported the results of standardized seine surveys between 1986 and 2015 and found that that green sunfish constituted up to 0.24% of the catch in the lower Green River and 0.29% of the catch in the lower Colorado River (between Cisco Landing and the junction with the Green River). No bluegill were reported in the sampling (Breen et al. 2016). Staff from the UDWR's Moab Field Office report that collection of 11 green sunfish and 4 bluegill in 2013, 3 green sunfish and 1 bluegill in 2014, and 1 green sunfish and 1 bluegill in 2015 during standardized sampling in the Colorado River between Moab and the confluence with the Green River (D. Elverud, personal communication).

In general, redear sunfish appear rare in large, turbid river systems, even in their native range. McClelland and Sass (2008) reported data collected from 27 sites spanning 280 miles of the Illinois River.

Samples were collected yearly between 1957 and 2007. Redear sunfish were not collected in most years and were rare (<0.01% of catch) in the years that they were collected. Winemiller et al. (2000) reported the collection of redear sunfish in oxbow lakes but not the main stem of the Brazos River, Texas. Slipke and Maceina (2005) found that redear sunfish were more common in backwaters than the main stem of Alabama rivers.

Conclusions:

There are sections of the Colorado River near Lake Havasu where redear sunfish thrive. These sections have low water velocity, relatively clear water, and ample vegetation (C. Karp, United States Bureau of Reclamation, personal communication). Data appears to indicate that the tributaries to Lake Powell provide less optimal habitat to redear sunfish. Tributaries to Lake Powell score zero on the Twomey et al. (1984) model, indicating that the habitat is "not suitable" to redear sunfish. The closely related bluegill and green sunfish are found in low numbers in Lake Powell tributaries. It is believed that most bluegill and green sunfish found adjacent to Lake Powell were fish born in Lake Powell that migrated into the tributaries. The tributaries likely provide poor spawning habitat for sunfishes. There are small populations of bluegill and green sunfish in the Colorado River near Moab. This section of the river is slower velocity and has numerous backwaters and likely supports some reproduction. It is anticipated that redear sunfish would perform similarly to bluegill and green sunfish in tributaries to Lake Powell. Low numbers of redear may be found in the San Juan River and it is not likely that redear would be found in Cataract Canyon. Backwater habitats in some reaches of Lake Powell tributaries may provide conditions that could support redear but again, their reproduction would be similar to bluegill and green sunfish. Redear sunfish are not piscivorous (Minckley 1982) and thus escaped individuals would likely not feed on native fishes but still could compete for forage with native fishes. The effect that redear sunfish would have on native fishes is anticipated to be more similar to the effect that bluegill have than what green sunfish have because the diet of redear sunfish is more similar to bluegill than green sunfish (Minckley 1982).

Based on the data reviewed, it is difficult to determine how redear sunfish would perform in Lake Powell but Lake Powell provides suitable habitat for redear sunfish and they would like to do well in the reservoir. Redear sunfish would likely be popular among anglers if they perform as well as they have in Lake Havasu. This may motivate anglers to move redear sunfish via "baitbucket transfers", which would accelerate the spread of redear sunfish and could lead to their establishment in areas of more suitable habitat where they may have a greater effect on native fishes.

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